



90/0083  
Accepted PCT/PTC 20 MAR 2002

Patent Office  
Canberra

I, JONNE YABSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PQ 3263 for a patent by SOLA INTERNATIONAL HOLDINGS LTD filed on 21 September 1999.

WITNESS my hand this  
Twenty-sixth day of February 2002

*J R Yabsley*

JONNE YABSLEY  
TEAM LEADER EXAMINATION  
SUPPORT AND SALES

101089470

AUSTRALIA 20 MAR 2002

P/00/009

Regulation 3.2

**AUSTRALIA  
Patents Act 1990**

**PROVISIONAL SPECIFICATION**

Invention Title: **METHOD OF COATING AN OPTICAL ELEMENT**

Applicant: **SOLA INTERNATIONAL HOLDINGS LTD**

The invention is described in the following statement:

## METHOD OF COATING AN OPTICAL ELEMENT

### Field of the Invention

The present invention relates to a method of coating an optical element, together with the optical elements produced by the inventive method. The invention finds 5 particular use where the optical element is an ophthalmic lens, and in particular relates to a method of coating an ophthalmic lens by utilising improved in-mould coating techniques.

### Background of the Invention

The application of coatings to surfaces has been achieved in a variety of ways, 10 such as by spin coating, dip coating, spray coating, and flow coating techniques. While these techniques have been successful when used to coat smooth surfaces, such as the optical surface of single vision ophthalmic lenses, they have not been entirely satisfactory. For example, such techniques have often resulted in a build-up of a coating material at the outer edge of the lens that 15 causes optical aberrations.

Such techniques have proven to be even less satisfactory when used to coat irregular surfaces, such as those present on multi-vision ophthalmic lenses, particularly those made from plastic. Such lenses generally have segments that project abruptly away from at least one major optical surface of the lens. Coating 20 solutions applied to these optical surfaces by spin, dip, spray, or flow techniques must flow around and over these segments, with the resulting coating generally exhibiting flow marks around the projection and being thick at the intersections of the segment and the optical surface.

A further disadvantage of conventional techniques of applying coatings to optical 25 elements is that they often have high labour and capital requirements. Furthermore, any yield loss at the point of coating results in total loss of a high valued product at the end of its manufacturing cycle.

In response to these difficulties, an 'in-mould' coating technique was developed for manufacturing ophthalmic lenses. The method comprised applying a single coating to a face of a mould, partially curing the coating upon the mould, subsequently assembling the moulds, filling the moulds with a lens monomer, and

5       curing the lens monomer to form a hard lens.

However, a limitation of this in-mould technique is that a single coating does not allow for the provision of a coating that is both highly abrasion resistant and has excellent cross hatch adhesion to the lens substrate. Furthermore, it has not proven to be possible to incorporate other desirable optical properties to the

10      single coat produced by this technique.

It is an aim of the present invention to provide an improved in-mould coating technique that is capable of being used to produce coated optical elements such as ophthalmic lenses.

#### Summary of the Invention

- 15      The present invention provides a method of coating an optical element, the method using a mould having first and second mould sections that form front and back surfaces of the optical element, one of the mould sections having a casting face, the method comprising the steps of:
- 20            – applying a first coating layer to cover the casting face of a mould section, the casting face being capable of imparting a desired optical configuration on a surface of the optical element;
- 25            – partially curing the first coating layer, and/or removing solvent from the first coating layer, to provide at least weak adhesion of the first coating layer to the casting face, and to replicate the casting face in a substantially aberration-free manner;
- 30            – applying a second coating layer to the first coating layer to substantially cover the first coating layer;
- partially curing the second coating layer, and/or removing solvent from the second coating layer, to provide at least weak adhesion of the second coating layer to the first coating layer;

- filling the mould with an organic liquid material capable of hardening to a solid, preferably to a room-temperature stable solid; and
- hardening the organic liquid material so as to form the optical element adhered to the second coating layer.

5 The method of the present invention may additionally include an additional thermal post-cure cycle after the hardening of the organic liquid, after the optical element is removed from the mould. The method may also include the step of  
10 exposing the optical element to radiation (such as actinic radiation), to complete the reaction (and curing) of the two coating layers. These alternatives assist in ensuring that the final optical element has optimal properties.

Also, it is to be appreciated that the method may include the coating of subsequent layers over the second coating layer; there thus possibly being third,  
15 fourth, fifth etc coating layers, each similarly applied over the previous coating layer and then partially cured. In this respect, throughout this specification, reference to the partial curing of a coating layer is to be understood to mean reference to the curing step being such as to at least partially cure the coating layer. This is to encompass the possibility that each of the curing steps are  
20 conducted so as to completely cure the coating layers, if this is required.

Preferably, the first coating layer is applied to the casting face of the mould so as to completely cover the casting face. However, it should be appreciated that there may be manufacturing constraints that cause the covering not to be perfectly complete over all of the casting face, which may be acceptable in some  
25 circumstances, especially if the lenses are not to be tinted, the defects are very small or if they are at the periphery of the lens (outside of the normal region for vision), or the lenses are to be subsequently AR coated using vacuum coating techniques. Therefore, it will be appreciated that the covering of the casting face need only be substantially complete. Indeed, this may also be the case for the  
30 covering of the first coating layer by the second coating layer.

In a preferred form of the method of the invention, the second coating layer is applied to the first coating layer in a manner that does not cause crazing, delamination or removal of the first layer. By way of explanation, in order to effect adequate adhesion it will generally only be necessary to partially cure the

- 5 first coating layer. A partially cured system is not necessarily mechanically robust or impervious to the diffusion of solvent. Solvent diffusion into the first layer may lead to swelling followed by stress cracking. Alternatively, solvent diffusion may lead to the delamination of the weakly adhered first layer. In order to eliminate difficulties associated with solvent, a solventless primer coating may  
10 be utilised. Alternatively, appropriate solvents may be used that have a reduced tendency to cause stress cracking of the first layer.

The method of the present invention is thus capable of producing an optical element in the form of an ophthalmic lens having a thin, optically clear, aberration free, multilayer, abrasion-resistant coating on one or more of its optical surfaces.

- 15 The method provides a means of incorporating special features into the multilayer coating, in addition to high abrasion resistance, such as impact enhancement, photochromic dye incorporation, electrochromic incorporation, and tint incorporation. It is also possible to incorporate multilayer coatings of specified refractive indices to achieve anti-reflection, hydrophobic optical surfaces, etc.  
20 Furthermore, the method is capable of producing an ophthalmic lens that is a substantially accurate reflection of the moulds from which the lens is cast. Further still, the method provides a technique that is equally useful in applying a multilayer coating to single, multifocal or progressive lenses, and that achieves a high yielding manufacturing process for producing premium quality ophthalmic  
25 lenses.

- The coating layers applied by the method of the present invention are ideally substantially free from surface aberrations that may arise due to non-uniformity of the thickness of the coating solution, flow marks, coating buildup (particularly at the segment lines and edges of ophthalmic lenses), and crazing of intermediate  
30 layers. Additionally, the coating layers preferably substantially exactly replicate

the mould surface from which an ophthalmic lens is made and consequently provide an optical surface having the desired surface configuration.

As used throughout this specification, the following terms have the following meanings:

- 5      a) "Optically clear" means free from haze or other interference that prevents an object on one side of a lens from being seen clearly by an observer on the other side of a lens;
- 10     b) "Aberration-free" means that an object on one side of a layer of the coated lens does not appear to be bent, twisted or distorted to a viewer on the other side of the lens;
- c) "Optical surface" means one of the surfaces which provides optical correction;
- d) "Lens substrate" means an organic liquid which when cured forms a solid at room temperature and provides optical properties consistent with an ophthalmic lens;
- 15    e) "Optical element" includes in its meaning lenses for optical devices such as cameras, microscopes, telescopes, or for the refracting or reflecting of light (eg mirrors) in any scientific or medical device, and of course also includes ophthalmic lenses of all types.

#### Description of the Invention

- 20    Each of the coating layers applied using the method of the present invention are preferably thin, although their thickness will depend somewhat on the function of the particular coating layer. If the first coating layer is intended to be a hard coat, it is preferably thin (typically having a thickness of from about 0.5 to 50 microns, although more preferably of from about 0.8 to 10 microns, but most preferably of
- 25    from about 1 to 5 microns thick).

In one form of the invention, the second coating layer may be intended to act simply as an adhesion promoter between the first coating layer and the lens

substrate formed by the polymerisation of the organic material. This layer is preferably also thin, with a typical range of 0.1 microns to 50 microns, more preferably 0.2 to 10 microns, but most preferably 0.2 to 1 micron.

However, in addition to the second coating layer providing a benefit in adhesion  
5 between, in one form, a very abrasion resistant (hard) first coating layer and the lens substrate, it can also serve other functions. These other functions may be such as:

- (i) the incorporation of dyes to provide a tint for the final product;
- (ii) the incorporation of a photochromic dye to provide a light sensitive  
10 variable transmission;
- (iii) the incorporation of an electrochromic dye which upon the application of a current will change colours and vary the transmission;
- (iv) the incorporation of a liquid crystal material, which upon the application of an electric field will orient in accordance with the applied electric field and  
15 provide variable transmission of a particular polarisation of light; and
- (v) inherently provide retention of impact properties of the final lens, especially after overcoating with an antireflection stack.

Alternatively, these product enhancing features may be separately (or in combination) incorporated into third, fourth (and so on) subsequent coating  
20 layers, rather than be incorporated into the second coating layer.

With further reference to the thickness of coating layers, in the event that the first coating layer is to act as a permanent mould release agent to facilitate the removal of the lens from the mould, or as a hydrophobic or oleophobic layer, it will preferably be very thin. In this form, the first coating layer preferably has a  
25 thickness from 1 nm to 1 micron, although more preferably from about 1 nm to 100 nm, but most preferably from about 1 nm to 30 nm.

The second coating layer (which in this form of the invention then preferably acts as the abrasion resistant hard coat) is preferably thin. In this form, the second coating layer preferably has a thickness in the range from about 0.5 to 50

microns, more preferably from about 0.8 to 10 microns, but most preferably from about 1 to 5 microns thick.

In this form of the invention, a third coating layer then preferably acts as an adhesion promoter between the second coating layer and the lens substrate  
5 formed by the polymerisation of the organic material. The third coating layer is also preferably thin, with a typical thickness ranging from 0.1 microns to 50 microns, preferably from 0.2 to 10 microns, but most preferably being from 0.2 to 1 micron.

If the method of the present invention is to be used to produce an ophthalmic lens  
10 carrying an abrasion resistant, anti-reflection multilayer stack, the first coating layer will preferably be very thin and act as a mould release/hydrophobic layer. A series of layers, comprised of multilayers of metal oxides (known in the art as an anti-reflection stack), may then form a middle coating layer. This middle coating layer may also act as the hard coat, and may have a thickness of about 0.5 to 20  
15 microns, more preferably of about 1 to 10 microns, but most preferably of about 1.5 to 5 microns. Alternatively, another coating may be applied which acts as the abrasion resistant hard coat. In this form, this coating layer preferably has a thickness in the range from about 0.5 to 50 microns, more preferably from about 0.8 to 10 microns, but most preferably from about 1 to 5 microns thick.

20 The anti-reflective coating on the front surface of the optical lens may be a standard multi-layer anti-reflective coating. The number and/or thickness of the layers in the standard multi-layer anti-reflective coating may be selected utilising suitable computer software. The layers may include alternate high and low refractive index layers.

25 The low and high refractive index layers may be formed from any suitable material. The low and high refractive index layers may be formed of a dielectric material. Preferably, the dielectric layers will be formed from metal oxides, fluorides or nitrides. Metal oxides which may be used for forming transparent layers include one or more of SiO, SiO<sub>2</sub>, ZrO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, TiO, TiO<sub>2</sub>, Ti<sub>2</sub>O<sub>3</sub>, Y<sub>2</sub>O<sub>3</sub>,  
30 Yb<sub>2</sub>O<sub>3</sub>, MgO, Pr<sub>2</sub>O<sub>3</sub>, Ta<sub>2</sub>O<sub>5</sub>, CeO<sub>2</sub> and HfO<sub>2</sub>. Fluorides that may be used include

one or more of MgF<sub>2</sub>, AlF<sub>3</sub>, BaF<sub>2</sub>, CaF<sub>2</sub>, Na<sub>3</sub>AlF<sub>6</sub>, Ta<sub>2</sub>O<sub>5</sub>, and Na<sub>5</sub>Al<sub>3</sub>Fl<sub>14</sub>. Suitable nitrides include Si<sub>3</sub>N<sub>4</sub> and AlN.

A silica (SiO<sub>2</sub>) or magnesium fluoride (MgF<sub>2</sub>) material is preferred for the low index layers, while a combination of titanium and praseodymium oxide (TiO<sub>2</sub> + Pr<sub>2</sub>O<sub>3</sub>) is preferred for the high index layers. Such a combination may have a refractive index at 500 nm of approximately 2.15.

In a preferred form, the anti-reflection coating may include a total of 4 to 6 alternating high and low index layers, preferably 4 to 6 alternating layers with thicknesses shown below.

Layer Substrate	Material	Thickness (nm)
1	SiO <sub>2</sub>	173
2	Pr <sub>2</sub> O <sub>3</sub> /TiO <sub>2</sub>	23.4
3	SiO <sub>2</sub>	18.7
4	Pr <sub>2</sub> O <sub>3</sub> /TiO <sub>2</sub>	93.2
5	SiO <sub>2</sub>	82.6

10

The final coating layer may then be the adhesion promoter layer that may incorporate other features, such as those listed above.

Alternatively, a suitable abrasion resistant, anti reflection, multilayer ophthalmic lens can be achieved by applying a single layer coating of specified refractive index to the mould. In this form of the invention, the second coating layer then preferably acts as the abrasion resistant hard coat. In this form, the second coating layer preferably has a thickness in the range from about 0.5 to 50

microns, more preferably from about 0.8 to 10 microns, but most preferably from about 1 to 5 microns thick. A third coating layer then preferably acts as an adhesion promoter between the second coating layer and the lens substrate formed by the polymerisation of the organic material. The third coating layer is 5 preferably thin, with a typical thickness ranging from 0.1 microns to 50 microns, preferably from 0.2 to 10 microns, but most preferably being from 0.2 to 1 micron.

The method of the invention optionally permits the use of subsequent coatings being applied via conventional means, such as by normal spin, dip or vacuum applications, after a multilayer in-mould coated lens has been manufactured in 10 accordance with the invention. For example, a highly abrasion resistant, multilayer, in-mould coated lens may be subsequently coated with a multilayer antireflection coating stack via conventional technology.

A number of classes of reactants can be selected to formulate coating resins. However, it will be appreciated that the class of reactants selected will depend 15 upon the particular property sought. For instance, a skilled addressee will be familiar with suitable classes of materials for use in providing abrasion resistant coating layers, adhesion promoting coating layers, single- and multi-layer antireflection coatings, and impact enhancing coating layers.

With reference now to the manufacturing process, moulds used in the 20 manufacture of ophthalmic lenses from organic materials are generally made from glass or metal and typically have first and second mould sections which are mounted in a gasket to form the front and back optical surfaces on the lenses. At least one of these sections has a surface that forms a finished optical surface. Depending upon the particular application, a permanent or semi-permanent 25 treatment may be applied to facilitate mould release.

The coating layers of the method of the present invention may be applied to one or more of the mould surfaces by a variety of techniques including spraying, dipping, brushing, flow coating, spin coating and the like.

If any of the coating compositions include a solvent, the solvent may be, and preferably is, removed prior to the deposition of subsequent layers or prior to the moulds being filled. The solvent removal preferably occurs either in concert with the partial curing or as a separate process that is preferentially conducted prior to  
5 the partial curing. The solvent removal may be achieved by the use of infra-red radiation, microwave radiation or heat.

Each coating layer is partially cured and/or has any contained solvent removed, preferably to a degree that wherein the coating layer forms a substantially insoluble dry film that exactly replicates the casting face of the mould in a  
10 substantially aberration-free manner. This may be achieved by either heating the coating layer for a time sufficient to form the dry film, or by exposing it to activating radiation for a time sufficient to form the dry film.

Whichever technique is employed, it is preferred that the coating layer be prepared in a predetermined fashion according to the chemistry of the  
15 subsequent layers. For example, if a coating layer is under-cured, it may produce a hazy film and it may also exhibit poor abrasion resistance. However, if a coating layer is over-cured, it may exhibit unacceptable adhesion. When thermal techniques are employed, it has been found that a coating layer can be successfully partially cured by exposing it to temperatures in the range of about  
20 35°C to 130°C for about one to thirty minutes.

For example, if a coating layer contains an unsaturated monomer, such as an acrylate, the coating layer may be reacted (cured) until it exhibits a degree of unsaturation of about 30% to 90% of the unsaturation it possessed prior to reaction. Ideally, this may be achieved through the use of thermal energy  
25 initiating a thermal initiator, or activating radiation such as ultraviolet light (with an appropriate initiator in the coating) or electron beam radiation. Preferably, such a coating layer may be reacted (cured) until it exhibits a degree of unsaturation in the range of about 40% to 75%, and most preferably from about 55% to 70%, of the unsaturation it possessed prior to reaction. In this respect, coatings that have  
30 a degree of unsaturation above about 90% provide a hazy film or are dissolved by the subsequent layer or monomer (i.e., one which is not optically clear) on the

final ophthalmic lens and may also exhibit poor abrasion-resistance. However, those that have a degree of unsaturation below about 30%, generally exhibit unacceptable adhesion to the final product.

In another example, the coating layer may be made up of a polysiloxane which  
5 requires thermal energy to remove solvent and hydrolysis product (typically methanol or ethanol) with very little, if any, additional condensation occurring. The subsequent coating layer is preferably of a suitable chemistry so as to not cause crazing. For example, the subsequent coating layer may be a second polysiloxane of different chemical makeup to the first coating layer that can be  
10 cast without the necessity for solvent.

After being partially cured, or after having contained solvent removed therefrom, a coating layer in the method of the invention will be considered dry, although it may be tacky to the touch. Additionally, the coating layer will generally not flow by itself, although touching it with finger pressure can deform it. Furthermore, it  
15 will be appreciated that the coating is not abrasion-resistant at this point.

In relation to the partial curing of a coating layer, the specific technique used to bring about partial curing (or partial 'reaction') may be selected to suit the nature of the coating composition. When polysiloxane coatings are used, containing partially hydrolysed and partially condensed glycidoxypropyltrimethoxsilane,  
20 methacryloxypropyltrimethoxsilane, allyltrimethoxsilane or vinyltrimethoxsilane, there is the option of either further advancing the condensation to provide a gelled network or polymerising through the organic component of the coating layer. Network formation via the organic component can be effected, for example, by ring opening the glycidoxyl portion of the  
25 glycidoxypropyltrimethoxsilane using cationic initiators or curing catalysts, curing the ethylenic portion of the methacryloxypropyltrimethoxsilane, vinyltrimethoxsilane or allyltrimethoxsilane using cationic or free radical initiators, etc.

Other techniques suitable for curing (or reacting) the coatings will be obvious to  
30 those skilled in the art.

After the desired level of curing (or solvent removal) for the final coating layer is obtained, the mould is preferably assembled and filled with liquid organic material to provide the lens substrate. A wide variety of thermosetting materials may be employed. In the preferred form, all that is necessary of such materials is that

- 5 they be capable of solidifying to form a room-temperature stable, optically clear, optical element. Examples of useful thermosetting materials include allyl diglycol carbonate monomer (also known commercially as CR-39), acrylate monomers, and acrylate oligomers, thiourethanes, combinations of multifunctional thiols with acrylates, etc.

10 Once the mould is filled, the organic liquid is hardened by any suitable technique. For example, allyl diglycol carbonate may be hardened by subjecting it to heat in the range of 35°C to 120°C for up to 24 hours in an oven or in a series of waterbaths, according to a predetermined schedule in the presence of a suitable polymerisation agent.

15 As the organic liquid hardens, the coating layer adjacent to the organic liquid, and the subsequent coating layers in direct contact, form an intimate bond providing excellent adhesion. The adhesion between individual coating layers, and with the lens substrate, is preferably such that the structure can survive accelerated weathering, outdoor weathering, and 3 hour boil tests and the like, 20 without loss of adhesion, excessive crazing, delamination, etc. The loss of adhesion may be as measured by an industry standard tape test, such as a test where a series of cross-hatched regions are formed on a lens surface, a pressure sensitive adhesive tape is applied, and the tape is then quickly removed.

As the organic liquid hardens, the coating is further reacted so that once 25 hardening of the substrate is completed the coating is rendered abrasion-resistant. Once hardened, the cast ophthalmic lenses are removed from the mould. As the adhesion of the multilayer coatings to the lens substrate is greater than the adhesion to the face of the mould, the ophthalmic lens separates essentially completely from the mould. It is preferable that the adhesion of the 30 first layer to the mould is such that this layer does not separate from the mould

during processing, until the mould is opened to prevent contamination of the mould surface by water, etc during processing.

An ophthalmic lens so produced may be used as is or alternatively may be post-reacted. Post-reaction may be accomplished by the same techniques utilised to  
5 initially partially cure the coating layers. In this respect, the conditions employed during post-curing will typically be sufficient to ensure essentially complete curing of the coating layers. It will be appreciated that a post-curing step will be most important in systems such as polysiloxane systems, in which heating to 90 - 120°C for a period of up to 4 hours is desirable to substantially fully condense the  
10 polysiloxane coating layers and develop optimal mechanical properties.

The method of the present invention may be used to coat the front mould, the back mould, or both moulds. Thus, the in-mould coating technique of the invention is applicable to both finished and semi-finished lenses.

By using standard ophthalmic industry abrasion tests, the abrasion resistance of  
15 ophthalmic lenses produced in accordance with the method of the present invention can be demonstrated. In this respect, it has been found that for such lenses, the haze developed following a Bayer abrasion test was less than 1/2.5 as severe as an uncoated CR-39 lens. The haze developed following a steel wool abrasion test was less than 1/10 as severe as an uncoated CR-39 lens. In  
20 comparison, a conventional single layer in-mould coating, with sufficient adhesion to the lens substrate and adequate mould release properties, resulted in haze levels following a Bayer abrasion test of only 1/1.5 to 1/2 of that for an uncoated CR-39 lens.

Surprisingly, the interference rings associated with index mismatch between  
25 coating and substrate have also been shown to be reduced in comparison to conventionally applied coatings. It is speculated that this performance enhancement is attributable to a diffuse interface between the respective coating layers and provides a substantial improvement compared to a multilayer coating using sequential conventional processes. It further provides a substantial saving  
30 in cost and time of production over conventional processes.

Examples of materials able to be used to formulate the various layers include materials that have a reactive ethylenically unsaturated group, such as acrylates, methacrylates, acrylic anhydrides, ethylenically unsaturated anhydrides, olefinic compounds, acrylamides, ethylenically unsaturated amides and urethanes, vinyl esters, vinyl ethers, vinyl halides, vinyl epoxy resins, vinyl silanes and siloxanes, vinyl heterocycles, melamines, and prepolymers and polymers of these materials. These materials may be mono- or polyfunctional.

Further examples of materials able to be used to formulate the various layers include organosilanes and organosiloxanes. Such materials include vinyl silanes, allyl silanes and (meth)acrylsilanes. Other organosilane and organosiloxane include tetra alkoxy ortho silicates, alkyl trialkyloxy silanes, dialkyl dialkyloxy silanes, mercaptosilanes, isocyanato silanes, etc. Also included are oligomeric materials based upon the aforementioned organosilane and organosiloxane species.

In addition to silicon based oxides for the abrasion resistant coat, other metal oxides can also be used. Materials such as tetramethoxy titanate and other metal oxides based on cerium, tin zirconium, etc. and their derivatives can be used as monomers or can be prereacted in a similar manner to the functional silanes to form a prepolymer coating with similar coating properties to other commercial polysiloxanes. These materials provide advantages over polysiloxanes in that they provide a higher refractive index and therefore are suitable for producing index matched coatings for higher index substrate materials such as FINALITE (registered trademark of Sola International Inc) or MR 6 (registered trademark of Mitsui Toatsu).

25

Further examples of materials able to be used to formulate the various layers include thiols. These materials may be mono- or polyfunctional.

Further examples of materials able to be used as coating layers are various commercial compositions based upon the aforementioned monomeric components. Specific examples of such materials include: SDC 1154, Silvue 339, PPG 1080, Suminal G35, GE 8556 and GE 8553 and GE 8566, etc.

The nature of the reaction initiator utilised in the composition is dependent upon the ethylenically unsaturated material used. For example, for those ethylenically unsaturated materials that undergo free radical polymerisation, suitable initiators  
5 are compounds that liberate or generate a free-radical on addition of energy. Such initiators include peroxy, azo, and redox systems each of which are well known and are described in polymerisation art.

Included among the free-radical initiators are the conventional heat activated catalysts such as organic peroxides and organic hydroperoxides. Examples of  
10 these catalysts are benzoyl peroxide, tertiary-butyl perbenzoate, cumene hydroperoxide, azobis(isobutyronitrile) and the like.

The preferred catalysts are photopolymerisation initiators. Included among such initiators are acyloin and derivatives thereof, such as benzoin, benzoin methyl ether, benzoin ethyl ether, benzoin isopropyl ether, benzoin isobutyl ether, and  
15 .alpha.-methylbenzoin; diketones such as benzil and diacetyl, etc.; organic sulfides such as diphenyl monosulfide, diphenyl disulfide, decyl phenyl sulfide, and tetramethylthiuram monosulfide; S-acyl dithiocarbamates, such as S-benzoyl-N,N-dimethyldithiocarbamate; phenones such as acetophenone,  
.alpha.,.alpha.,.alpha.-tribromacetophenone,.alpha.,.alpha.-diethoxyacetop  
20 henone, .alpha.,.alpha.-dimethoxy-.alpha.-phenylacetophenone, o-nitro-.alpha.,.alpha.,.alpha.-tribromacetophenone, benzophenone, and p,p'-bis(dimethylamino)benzophenone; aromatic iodonium and aromatic sulfonium salts, sulfonyl halides such as p-toluenesulfonyl chloride, 1-naphthalenesulfonyl chloride, 2-naphthalenesulfonyl chloride, 1,3-benzenedisulfonyl chloride, 2,4-  
25 dinitrobenzenesulfonyl bromide, and p-acetamidobenzenesulfonyl chloride.

The reaction catalysts employed with silane and siloxane materials is preferably ammonium perchlorate and aluminium acetyl acetonate which can open epoxy rings and act as high temperature acids.

The coating compositions can include a variety of other ingredients such as compatible monomers and polymers, stabilizers, antioxidants, flexibilizers, colorants (e.g., dyes and pigments), reinforcing fillers, surfactants, flow aids, levelling agents, hardness enhancers (e.g., colloidal silica), refractive index modifiers (eg titanium dioxide, zirconium dioxide, antimony oxide, etc), antistatic agents and the like. Additionally, solvents may be utilised to facilitate preparation and application of the compositions.

It should be reiterated that by utilising the techniques of the present invention, interference rings which arise from a mismatch of the refractive index of the coating layers or between the coating layers and the substrate are minimised, enabling the use of refractive index mismatched coatings. However, there is a desire to match the refractive indices of each coating layer and the lens substrate as closely as possible to minimise the potential for interference rings.

In order to modify the refractive index of a coating without changing the chemistry of the coating formulation, very small particulate fillers can be added. Titanium dioxide, silicon dioxide or layers of silicon dioxide on titanium dioxide, tin oxide, etc have been used for this purpose. The average particle size is between 10 nm and 80 nm diameter, preferably between 20nm and 50 nm.

To ensure that these particles are substantially uniformly distributed throughout the coating layer and not agglomerated, a combination of surface treatment of the particles, grafting of a compatible monomer onto the surface of the particle, and/or use of surfactants or levelling agents are used. The loading of these particles is dependent on the refractive index of the coating matrix material, the refractive index of the particulate filler and the refractive index desired, but typically is in the range of 5% to 50% by weight of the final coating.

Particles can be added to all layers, including the abrasion resistant coating and the primer coating in order to achieve the desired refractive index system. By utilising these particles, a refractive index matched, low haze coating can be achieved for a range of chemistries.

These particles are sometimes added in order to increase the abrasion resistance of the coating.

Examples of suitable solvents include water, alcohols, esters, ethers,  
5 halogenated hydrocarbons, aliphatic hydrocarbons, aromatic hydrocarbons, fluorocarbons, ketones, heterocyclic liquids, etc.

Finally, it will be appreciated that other variations and modifications may be made to the methods and compositions described herein without departing from the scope of the present invention.

10

21 September 1999

PHILLIPS ORMONDE & FITZPATRICK

Attorneys for the Applicant:

SOLA INTERNATIONAL HOLDINGS LIMITED